Report TN 74o1

TRANSNUKLEAR GMBH

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"GOSLAR" Package Design

Safety Report

April 1974

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Introduction

The objection of this report is to demonstrate the conformity of the Goslar package design to the regulations for a "Large source" of multilateral approval.

The Goslar packaging was designed and built in 1964/65 against the U.S. proposed rules 1o CFR Part 72 of Sept. 18, 1961, and has been approved by the German competent authority (PTB and BAM) on July 6, 1965, for shipments of spent MTR fuel elements.

After adoption of the 1967 IAEA regulations, the container was classified as Typ A, fissile class III. Shipments of spent MTR fuel were performed under special arrangements in Germany, Austria and Belgium.

The packaging has now been modified by adding shock absorbing and heat insulating covers to make it a Typ B packaging for a large source subject to multilateral approval.

The principal characteristics of the modified packaging are as follows:

- large source package for shipments of spent MTR fuel elements (classical type), subject to multilateral approval

- fissile class II, admissible number: 2

- decay heat is transmitted by natural convection at the surface of the package

- primary heat transfer medium is air

- shielding is by lead of about 2o cm thickness.

In case of fire, lead can melt up to a thickness of not more than about 6 cm. Top and bottem are protected against lead melting by insulating covers

- nuclear safety is accomplished by use of a poisoned basket (Al + o,9 % Cd)

- the package has to be shipped as a full load. Total weight about 11 t. Max. Dimensions: ca. 12oo mm diameter, 18oo mm height.

I. Description of fuel elements

The material to be shipped will be classical spent MTR- fuel elements from the following reactors:

- GKSS FRG 1 and FRG 2, located in Geesthacht/FRG

- ASTRA at Seibersdorf/Austria

All the fuel elements are of the plate type (either bent or straight), and their properties are within the following limits:

- cross section max. 85 x 78 mm
- total length 63o - 95o mm
- active length 6oo mm
- number of plates 12 - 23
- enrichment 8o - 9o % (zero burn up)
- U-235 content max. 4oo g (zero burn up)

Calculation of decay heat

Following ORNL-NSIC-68, the decay heat of GKSS fuel elements presently discharged is

	Operating power	Operating time	decay heat per elem. 12o d	15o d	2oo d
FRG-1	125 kW	525 d	77 W	62 W	46 W
FRG-2	375 kW	175 d	142 W	115 W	85 W

In 1974 and 75 the power of FRG-2 will be increased step by step up to 8oo kW/element, the decay heat will then be

FRG-2	8oo kW	13o d	257 W	2oo W	15o W

Design heat load for the cask is 3.2 kW (13 elements), see chapter IV.

II. Description and characteristics of the Goslar packaging

1. General description

The Goslar packaging design in its original version is given on the manufacturers drawings

BMA No. 915 - 287 - o through - 7

The modifications are shown on Transnuklear drawings

TN 1-15o-o16-o6-oo through -o2

The packaging consists of

- a cylindrical body
- a lid
- covers at top and bottom
- a basket for 13 MTR fuel elements

Main dimensions are

over all diameter	123o mm
over all height	177o mm
cavity diameter	483 mm
cavity height	96o mm

weight (nominal)

empty packaging (incl. basket, excl. covers)	1o.25o kg
13 fuel elements max.	75 kg
total package weight (incl. covers)	1o.57o kg
total weight as presented to crane hook (incl. chassis and yoke)	11.67o kg

2. Description of certain details

2.1 Body

The inner shell is formed by stainless steel sheet 19 mm thick, the outer shell by 16 mm mild steel clad with 1 mm stainless steel. 6o SS fins 5 x 76 x 1ooo mm are welded to the outer shell for heat transfer.

Lead is cast between the shells, its thickness is 2o5 mm.

There is a quick connection on the upper side and a valve at the lower end for drawing/flushing operations.

2.2 Lid

The lid is a SS shell filled with lead, fully recessed in the bod. There are 2o lid fixing bolts M 24 x 8o. They are stressed by compression. Tightness is accomplished by a flat gasket 11 x 57o x 53o type Rivalit "Triumpf", Shore hartness 65 - 7o.

2.3 Protectingcovers

The covers are made of 3 mm St 37-2 sheet filled with balsa wood and protected by paint, weight of one cover is approximately 12o kg. The covers are fixed to the body by 6 bolts M 24.

2.4 Equipment for handling

There are 2 lateral trunnion sockets 7o x 176 mm of SS type 43o1 for handling in vertical position by a special yoke.

2.5 Connections

At bottom there is a drain valve NW 8 protected by a cover plate. At top there is a quick connection NW 6 for venting/flushing, protected by a cover and also by the shockabsorber on top.

2.6 Basket

The fuel element basket consists of cast Al Mg 3- o,9 W % Cd alloy and has 13 lodgements of 81 x 87 mm.

Dimensions of the basket 481 Ø x 915 mm.

3. Materials

Stainless steels parts are of the following qualities:

4301
4306
4541

Mild steel parts are HI and HII.

Stainless steel plating is quality 4541.

Other materials see chapter 2

4. Quality assurance

The main materials (inner and outer shell etc.) used for fabrication have been tested in accordance with DIN 5oo49/3c.

Important weldings are X-rayed and approved by TÜV.

Final pressure and leak testing was performed by TÜV with satisfactory results. Hydraulic test pressure was 7 kg/cm^2(g) leak testing was performed with o,5 kg/cm^2(g) air pressure.

Test results are filed at TÜV Hannover and Transnuklear.

III. Conformity to the regulations for general design factures

The general packing requirements of the 1967 IAEA regulations

- C-2.1
- C 3
- Annex II

are meet, as can be seen from the drawings and/or Annex A to this chapter.

As concerns a possible pressure build up it is to be noted that transport will be performed dry.

Annex A: Shielding calculation

1. We assume 13 FRG-2 elements with an operating power of 8oo kW during 13o d and a 12o d cooling period.

2. Source strength
   Following ORNL 2127, we get
   (No25= 5,72 x 1o ^{25})

   1 - 1,7 MeV (III) 1,26 x 10^{14} desintegr./sec
   > 1,7 MeV (IV) 4,6 x 10^{13} " "

3. Dose rate at contact and 2 m from lateral cask surface
   Shielding from inside to outside is

   - 1,9 cm stainl. steel
   - 2o,5 cm lead
   - 1,7 cm mild steel + SS cladding
   - o,7 cm SS (fins)

   Lead aequivalent is 23 cm Pb

   Self shielding of the cylindrical source following Rockwell (1) and assuming the Al-basket + fuel elements to have the density of Al

   μ_s Ro = o,o45 x 2,7 x 24 = 2,9

   μ_s Z = 1,44

   Z = 12 cm

	b1	b2	B	F(Q b)	dose rate at 2 m
III	13,3	14,7	5	5,4 x 10^{-8}	o,9
IV	11,8	13,2	5,5	2,5 x 10^{-7}	2,o
				total	2,9 mr/h

Dose rate at lateral contact is 21 mr/h.

4. Dose rate at top and bottom

Shielding of bottom	2,2 cm SS 24 cm lead 16 cm mild steel	26,2 cm Pb-aequiv.
Shielding of lid	1,4 cm mild steel 21,7 cm lead 26 cm SS	24,1 cm Pb-aequiv.

We only check shielding of the lid side.

The calculation follows Rockwell assuming a cylindrical source with selfabsorption.

Assumptions
- μ_s = o,125
- Source directly adjactent to lid
- covers neglected

Results:
- dose rate at contact 3o mr/h
- dose rate 2 m from lid 1,5 mr/h

5. Summary and conclusion

Dose rate	side	top	bottom
contact	21	3o	< 3o mr/h
2 m from surface	2,9	1,5	< 1,5 mr/h

for 13 fuel elements with Po = 8oo kW/BE, T = 13o d, t = 12o d.

The values are within the limits for a package transported as full load.

IV. Heat dissipation (Normal conditions)

1. Heat dissipation for accessible surface t_1 = 82 °C.

We assume natural convection and radiation to ambient to = 38 °C, in the finned region of the cask. Top and bottom heat transfer is neglected. The heat dissipation for a surface temperature of t_1 = 82 °C is calculated:

- Convection

  Using classical formula for convective heat transfer by fins we get (using formulas and notations given in ref 2)

α_o =	4.66 kcal/hm°C	F_R	= 9,1 m^2
α_R =	4,08 " "	F_o	= 3,0 m^2
ϑ =	0,81 (-)	F_1	=12,1 m^2
α =	3,5 kcal/hm°C		

$$Q\ conv. = \alpha\ F\ (t_1 - t_o)$$
$$= 3{,}5 \times 12{,}1 \times 44 = 1863\ kcal/h$$

- radiation

$$Q_r = \varepsilon \times C_s \times F \left[\left(\frac{T_1}{100}\right)^4 - \left(\frac{T_o}{100}\right)^4 \right]$$

$$Q_r = 0{,}8 \times 4{,}96 \times 3{,}45\ (159 - 94) = 887\ kcal/h$$

- Q_{total} = 1863 + 887 = 2750 kcal/h
  = 3,2 kW

2. Solar heat load

Horizontal surface	0,7 m^2	8000 kcal/m^2	12 h/d
Vertical surface	4,4 m^2	2000 kcal/m^2	12 h/d

averaged over 24 h, we get

Q Solar = 600 kcal/h

3. Temperatures in different parts of the cask

- Surface temperature taking into account solar load

$$t_1' = t_o + (t_1 - t_o) \times \frac{2750 + 600}{2750} = 91,6\ ^oC.$$

- cavity wall temperature t_2

  from outside to inside there are 3 layers

mild steel	S = 0,017 m	λ = 45	kcal/hm^{o}C	0,4
lead	0,205 m	24	" "	10,4
SS	0,019 m	13	" "	2,6
				13,4 ^{o}C

$$t_2 = t_1' + \Delta t = 91,6 + 13,4 = 105\ ^oC$$

- fuel basket outside temperature t_3

  Assuming only conduction by air through the gap of 1 mm between basket and cavity

$$t_3 - t_2 = 72\ ^oC$$

$$t_3 = 177\ ^oC$$

- fuel basket central temperature t_4

  Reference formula $t_4 - t_3 = \frac{Q}{4 \pi \lambda'} \times l$

where Q = 2750 kcal/h

l = 0,6 m (active length)

λ' = 25 (estimated conductivity of Al-basket with lodgements)

$$t_4 - t_3 = 15\ ^oC$$

$$t_4 = 192\ ^oC$$

4. Hottest fuel element temperature t_5

We consider a fuel element of 260 kcal/h in a central location and assume only conduction by air through the gap between fuel element and basket.

$$t_5 - t_4 = \frac{Q \times S}{\lambda\ F} = \frac{260 \times 0.0025}{0,035 \times 0,2} = 93\ ^oC$$

$$t_5 = 285\ ^oC$$

This figure is very conservative, because heat transfer by radiation and convection is neglected.

5. Conclusion

With a total decay heat load of 3,2 kW and individual fuel element decay heat not exceeding 300 W

- accessible surface temperature doesn't exceed 82 °C
- cask component temperatures are well acceptable in respect to the materials used
- fuel element integrity is maintained

V. Performance under accident conditions

1. Tests common to type A and B

   The packaging was already classified Typ A by PTB. The addition of the covers only improve the performance.

2. Punch test

   According to the "cask designers guide" (3) the minimum wall thickness t to avoid puncturing the outer shell of a lead cask is

$$t = \left(\frac{W}{S} \right)^{0,71}$$

where W = 24230 lb weight of packaging
S = 58600 lb/inch² tensile strength of shell

t = 0,534 inch = 13,6 mm

The actual shell thickness is 16 mm. So there is no risk of puncture.

3. 9 m drop

   The goslar cask was originally designed to withstand a 4,5 m drop without rupture of inner and outer shell and only minor reduction of shielding, if any. The lid cannot be lost due to special arrangement of the lid bolts which are only stressed in compression. Any deformation in the lid region will block the lid in position.

   The addition of the covers at top and bottom will more than compensate the additional drop height asked for by the present regulations.

   Sucessfull performance of the covers has been tested on a 1/4 scale model of the cask by BAM. Details of these tests are filed at BAM. These tests have also demonstrated that the covers will remain in place after the drop and therefore will protect top and bottom in the subsequent fire test. Reduction of cover thickness was about 30 %, so there remains sufficient insulating material thickness.

4. Fire test

The original safety analysis was based on the fact that lead will melt but would be confined in the outer shell.

To be conservative we now assume that molten lead can be lost.

From ref. 4. it can be calculated that in the lateral wall 24 % of lead is molten in the fire test corresponding to about 3,5 cm loss of lead shielding.

A computer calculation performed by BAM gave values of about 6,o cm of molten lead.

The increase in dose rate by loss of 6,o cm lead as compared to the normal transport condition is by a factor of

$$e^{+\mu t} = 32$$

where $\mu = 0{,}578\ ^1/\text{cm}$ (Pb, 1,5 MeV)
$t = 6$ cm

This value is less than the factor of 1oo allowed by the regulations.

At top and bottom and on the corners lead is protected by the insulating covers. So melting will not occur at these locations.

5. Summary and conclusion

After drop and fire test, there is no risk that the containment will fail. Increase in dose rate will be within acceptable limits. However, it cannot be demonstrated that the containment vessel will be leak tight after the tests. Therefore it will be demonstrated in chapter VI that release of activity will remain in the limits of IAEA C-6.2.3.2. (b).

11. Tightness, Release of activity under accident conditions

1. Normal conditions of transport

   Tightness of the containment vessel has been checked after manufacturing the cask.

   In addition the tightness will be checked before each transport by applying a o,5 kg/cm^2(g) pressure and checking for leaks with soap type solutions.

   It should be noted that pressure in the containment vesse is adjusted to o,6 kg/cm^2 before each shipment, so only inleakage of air is possible.

2. Release of activity under accident conditions

   Under accident conditions, the containment vessel will eventually not remain leaktight. Therefore we have to analyse the release of volatile fission products from the fuel elements.

   According to references 5,6 the difussion of fission gases in U-Al alloys or Al is neglectible as long as the melting point (64o °C) is not reached.

   Because the fuel elements will not exceed a temperature of about 4oo °C in an accident, a release of activity is not to be expected.

   Nevertheless we assume a 2o % release of all volatile fission products present in the cask at the date of transport.

2.1 Inventory of volatile fission products

- assumptions

  13 MTR fuel elements in the cask
  8oo kW operating power/element
  13o d operating time
  12o d cooling time
  4oo g U-235/element

- method of calculation
  following ORNL 2127 (7)

- result

	Activity/cask
Xe 131 m	2.39 Ci
Xe 133	o,24
kr 85	1145
I 131	1o.4

All other fission products either have higher evaporation temperatures than 6oo °C or are no longer present after 12o d of decay.

2.2 Activity release compared to IAEA C-6.2.3.2. (b)
We assume a 2o % release of the inventory and compare with the limits for casks requiring multilateral approval:

Isotope	2o % release (Ci)	Group	limit	formula for mixtures
Xe 131 m	o,48	V	2o	o,o24
Xe 133	o,o5	VI	1ooo	o,o
kr 85	229	VI	1ooo	o,229
I 131	~~1o,4~~ 2,08	III	3	o,693
			total	$\sum$ o,946 < 1

This result shows that activity release is within the limits of C-6.2.3.2 (b) though

- the maximum irradiation data and
- a very high release fraction of 2o %

are taken into account.

3. Compliance with C-6.2.3.1 (a)

The package design meets the criteria of C-6.2.3.1 (a) except for (i) and ix)
(iii) No continuos venting during transport.
(iv) No ancillary cooling system.
(v) No pressure relief system.

(vi) Due to the weight of the package there will be no air transport. Therefore no differential pressure in excess of o,35 kg/cm^2.

(vii) The interal pressure will even under accident conditions remain below 1 kg/cm^2 (g). Nevertheless the cask is designed for 3,5 kg/cm^2 (g) internal pressure and was tested at 7 kg/cm^2 (g).

(viii) Normal operating pressure is o,6 kg/cm^2.

(x) Tightness under normal conditions does not depend on mechanical cooling.

(xi) There is no liquid primary heat transfer medium and no radiactive content in liquid form.

VII. Criticality

The criticality evaluation has shown the following conditions to be acceptable

- 13 elements/cask each having up to 800 g U-235
- fissile class II, permissible number = 2.

Details of the calculation are given in the report of W. Comper KFZ Karlsruhe, ASS-report Nr. 181, Oct. 1973.

VIII. Inspection and operation of the cask

1. Inspection prior to first use

   The relevant inspections are described in chapter II. 4

2. Loading of the flask at reactor site
   (a more detailed handling instruction is in preparation)

   - On arrival, check internal gaseous contamination by controlled venting over the quick connection on top
   - remove lid, check for good condition of gaskets, connections, basket
   - put on lid again, check for tightness at o,5 kg/cm^2 (g) air pressure
   - remove lid, open drain valve and vent on top, place cask into the pond
   - load 13 MTR fuel elements
   - put the lid on and lift the cask to the pond surface
   - install lid fixing bolts
   - after draining, close drain valve and transfer the cask to the decontamination area
   - dry the flask by vacuum
   - leak testing at o,5 kg/cm^2 (g)
   - adjust pressure in the cavity to o,6 kg/cm^2
   - place the covers onto quick connection and drain valve
   - place shock aborbing covers.

Conclusion

The safety analysis has shown that in the Goslar packaging radioactive material of the following specification can be shipped.

- 13 classical plate type MTR fuel elements

- total decay heat 3,2 kW, individual fuel elements max. o,3 kW

- minimum cooling time 12o d

- maximum U-235 content 4oo g/fuel element (before irradiation)

Specification for shipment

- transport as a full load

- permissible number of cask per shipment: 2

- no supplementary operational controls are required during transport

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(5) M.B. Reynolds, Fission Gas Behaviour in the U-Al System, Nucl. Sc. and Eng., 3, 1958

(6) H.W. Castleman et al "Diffusion of Xe through Al and stainless steel", BNL 624, 1960

(7) I.C. Blomeke and M.F. Todd, U-235 Fission-Product Production, ORNL 2127, 1958

Abbreviations

PTB	Physikalisch-Technische Bundesanstalt, Braunschweig
BAM	Bundesanstalt für Materialprüfung, Berlin
TÜV	Technischer Überwachungsverein
BMA	Braunschweigische Maschinenbauanstalt, Braunschweig